Space Weather Technical Forecast

Issued on Saturday, 02 September 2023 at 01:30 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: G1-G2 Moderate storms likely 02-03 Sep due to CME arrivals. Chance of M-flares (R1-R2 Radio Blackout) 02 Sep, decreasing 03 Sep onward. Chance of Active high energy electron fluence by day 4 (05 Sep)

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate with a long duration M1.2 from AR3413 in the northwest, peaking at 01/0352UTC, with an associated CME. This is the largest and most complex region on the disc, but due to approaching the northwest limb is becoming increasingly hard to assess. However it appears to have maintained some complexity after the flare. Of the other sunspots AR3417 also has some complexity, consisting of a number of mature small negative spots, but has only seen minimal growth in trailer positive spots. AR3415 remains a simple bipolar region in the southeast, whilst AR3416 and AR3418 are small unipolar spots. A small, but currently unnumbered region has emerged in the northwest, to give six sunspots in total.

The CME produced by the M1.2 flare is moderately fast, but with the bulk of the material mainly directed north and ahead of Earth. However, arrival is anticipated around 03/0600 UTC. A further CME was also observed due to a small eruption from AR3413 in the southwest disc at 01/0620 UTC. This has been analysed as a slower and weaker CME, largely passing ahead and south of Earth, but with a chance of a glancing impact on day 3 (03 Sep).

Solar Wind / Geomagnetic Activity: Ongoing fast wind influence was observed, with a likely transition into the main core of fast winds from CH40/+ occurring. Solar wind speeds observed by ACE at L1were initially 400-450 km/s, but fairly rapidly increased 01/1750-1830 UTC to be 500-600km/s. Density was at average until this rise, then decreased to be below average. Despite this, the total Interplanetary Magnetic Field (IMF), Bt, persisted Weak to Moderate around 7-10nT, with the north-south direction, Bt, remaining variable between +9 nT and -10nT. Phi angle persisted positive (away from the Sun). Geomagnetic activity was Quiet to Active (Kp 1-4, with the Kp4 interval 01/1200-1500 UTC).

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux rose after 01/0400 UTC to be at S1 Minor Radiation Storm level between 01/00430-2010 UTC. A peak of 26 ppcc was observed at 01/0610 UTC. Observed flux has subsequently been gradually and erratically easing. GOES16 high energy (greater than 2MeV) electron flux was at background. The associated 24-hour fluence was well below the Active threshold, with 1.23e6 integrated pfu observed at 01/2100 UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Moderate to Low activity day 1 (02 Sep), with a further risk of M-flares from AR3413. This activity is expected to ease day 2 (03 Sep) onward, as AR3413 rotates over the northwest horizon, with the other spots on the disc currently smaller and simpler.

Solar Wind / Geomagnetic Activity: There are two main CMEs, and a further small glance possible in the forecast. The first is expected to arrive 02/2200 UTC +/- 9hours and is from the filament eruption on 30 Sep. The second is expected to arrive 03/0600 +/- 9hours, and is from the moderately fast CME which occurred alongside the M-flare of AR3413. A further small

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glance is possible on day 3 (3 Sep) from the subsequent small CME from AR3413 which left the Sun around 01/0600 UTC. Otherwise, current fast wind is expected to ease day 1 (02 Sep), with CME conditions then dominating, albeit easing day 3 and day 4 (04-05 Sep) until the next fast wind enhancement is possible, late on day 4 from CH42/+. Any early Active to G1 intervals due to onset of fast winds easing day 1, before CME arrivals bring an increasing likelihood of a period of G1-G2/Minor to Moderate storms, most likely day 2 (03 Sep), but with an ongoing chance of G1 Minor storms day 3 (04 Sep). There is a slight chance of G3 Strong Storms, mainly day 2. Activity then easing to be mainly Quiet to Unsettled by day 4.

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is expected to slowly decline towards background levels however, with a slight chance of further enhancements, perhaps above the S1 level given any further flaring of AR3413 over day 1-2 (02-03 Sep). High energy (greater than 2 MeV) electron flux is expected to be suppressed due CME arrivals, before rising as solar wind pressure eases later day 2 and day 3. Moderate to High flux then possible by day 3, but more likely day 4 (04-05 Sep). The associated 24 hour fluence is expected to remain below the Active level (1e8 integrated pfu) at first, but with an increasing chance of rising above by the end of day 4 (05 Sep).

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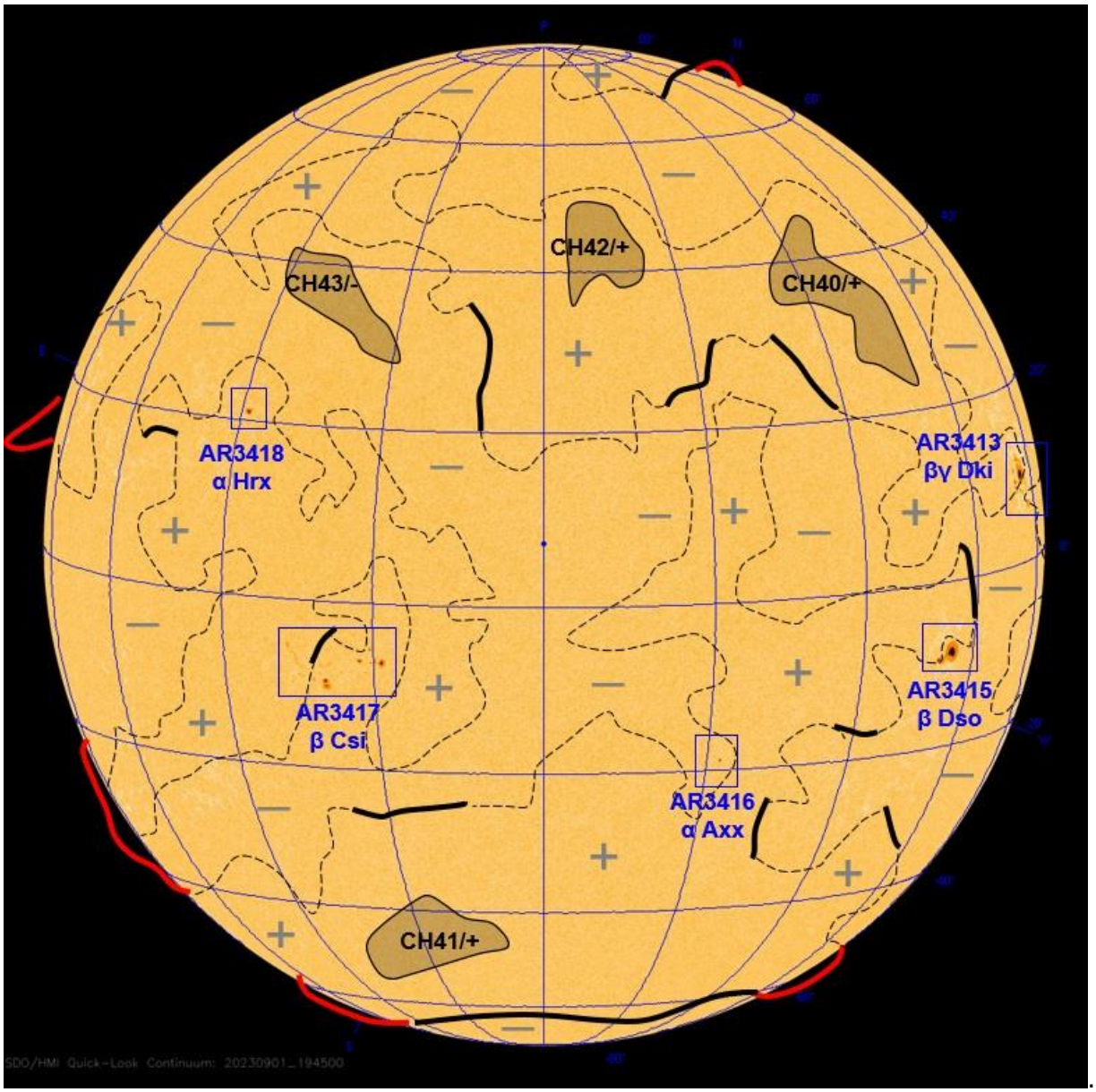
Figure 1. Solar Analysis Valid *.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

CME arrivals are forecast. The first from a filament eruption on 30/2000 UTC, and is forecast to arrive day 1 at 02/2200 +/- 9hrs. The second is from the M-flare of AR3413 which peaked 01/0352 UTC. This is currently anticipated to arrive day two at 02/0600 +/- 9 hours. There is then a third CME that followed this eruption, from AR3415 around 01/0620 UTC, this is a much weaker event, and likely only be a more glancing impact, but given the already disturbed environment, has the potential to increase activity again on day 3 (04 Sep).

Solar winds are currently elevated, near 600km/s, due to the ongoing fast wind influence due to the high speed stream (HSS) of CH40/+. This is likely to ease a little before the CME arrival later day 1 or early day 2, likely increasing solar winds again, to around 500-500km/s. The second arrival is then expected to follow, with the potential for solar winds to become strong, likely reaching 600-650km/s. Solar winds are then expected to gradually ease, day 3 onward but likely remaining dominated by the CME influence, with the potential for a further weak glance. A further small enhancement is possible later day 4 (05 Sep) however from the arrival of any associated fast winds from CH42/+ in the northern hemisphere, however this is low confidence.

Active to G1 Minor Storm intervals are possible at first due to the ongoing HSS, but otherwise geomagnetic activity is expected to be mainly Quiet to Unsettled before the CME arrival. The first arrival is expected to bring Active to G1 Minor Storms, with a chance of G2 Moderate storms from late day 1 (02 Sep), before the second CME arrives early day 2 (03 Sep). Activity is then likely to increase, with a spell of G1-G2 Minor to Moderate storms likely, and a slight chance of G3 Strong Storms. This activity is likely to ease day 3 (04 Sep), however ongoing CME effects along with the third glancing CME, may bring further G1 Minor Storms with a slight chance of G2 Moderate storms. Activity then easing further day 4, to mainly Quiet to Unsettled, but with a chance of Active to G1 Minor storm intervals later that day, from any HSS of CH42.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	40	70	30	10
Strong	G3	No	5	20	10	1
Severe	G4	No	1	2	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
31/0305	Partial	Filament	NW disc, but heading SE	610 km/s	02/2200 +/- 9 hrs	Nil.
01/0625	Partial	M1.2 AR3415	NW disc	1125 km/s	03/0600 +/- 9 hrs	Nil
01/1129	Nil	C2.8 AR3413	SW disc	431 km/s	04 Sep	Very low confidence.

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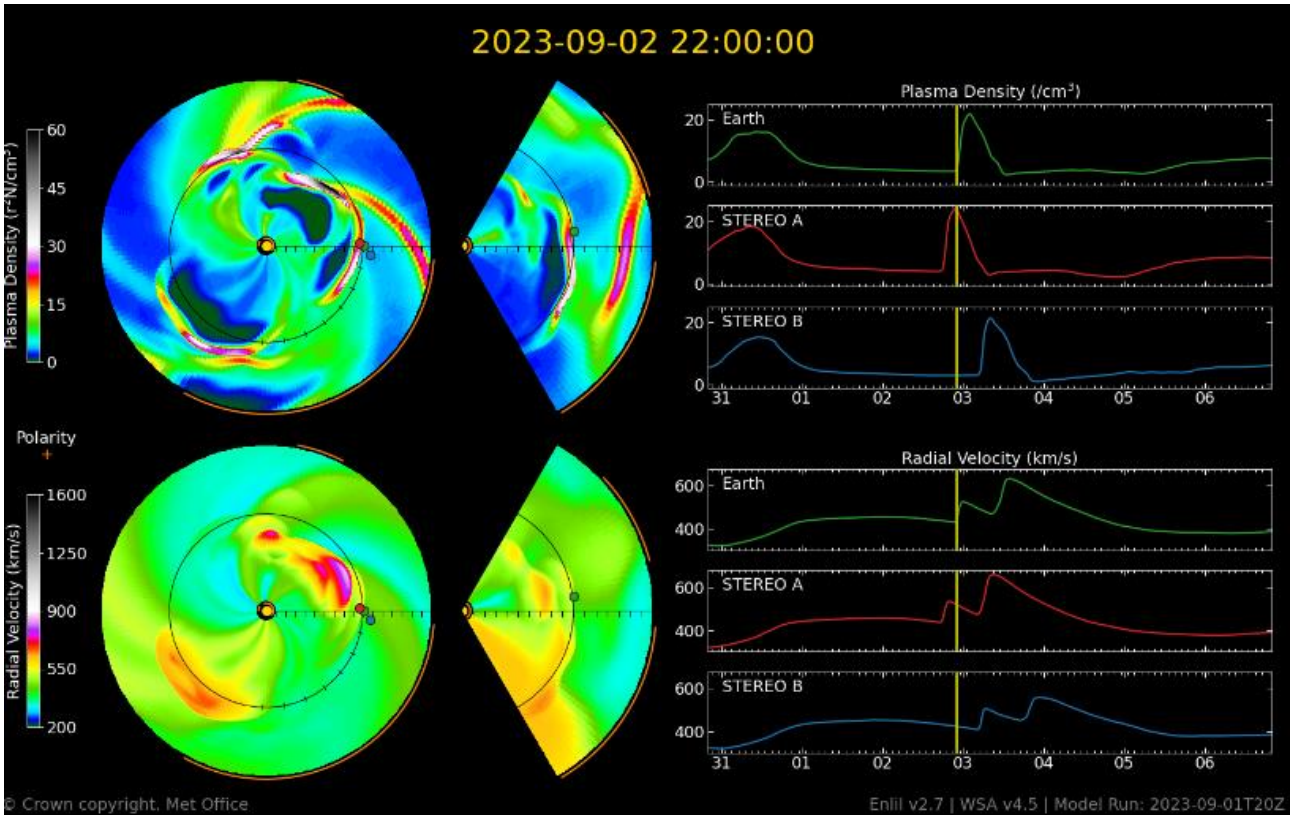
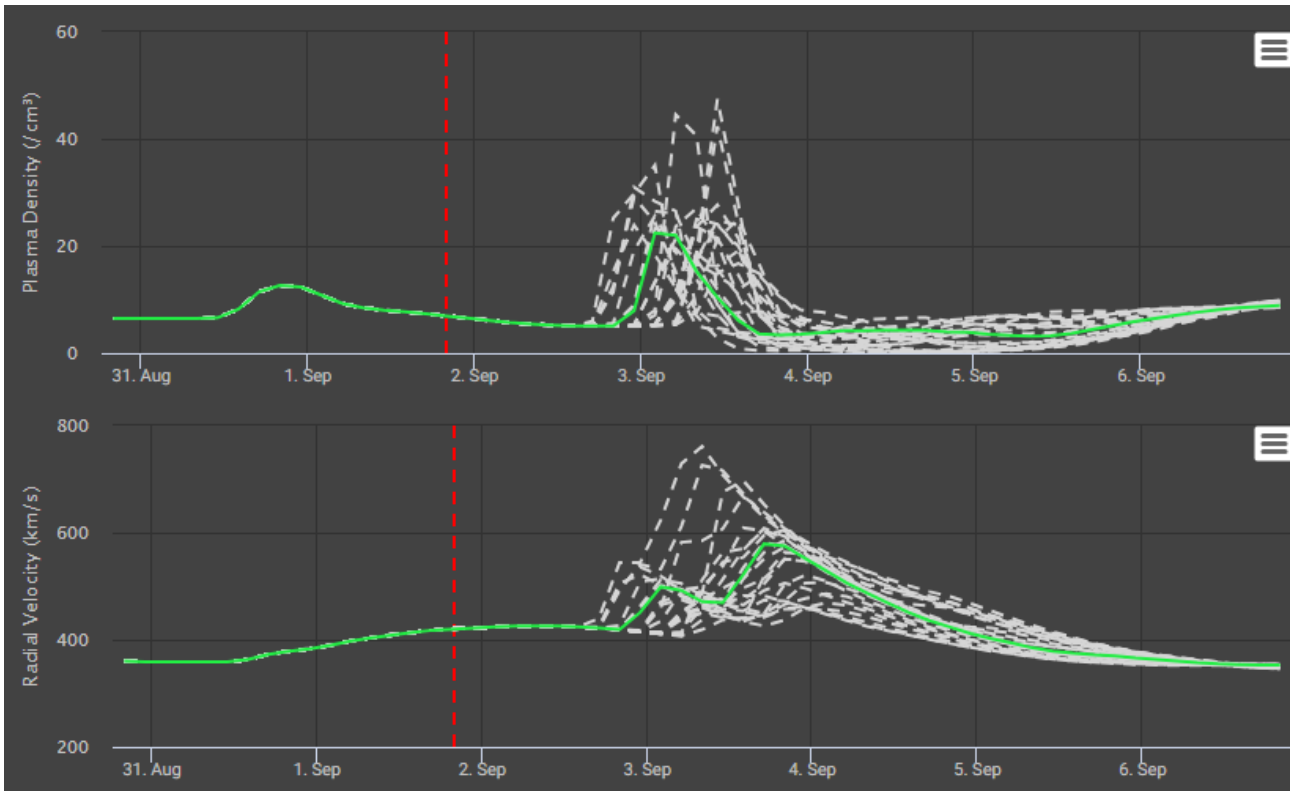
Figure 2: Enlil showing two potential CME arrivals, with ensemble. Impact of third CME is swamped by the ongoing conditions.





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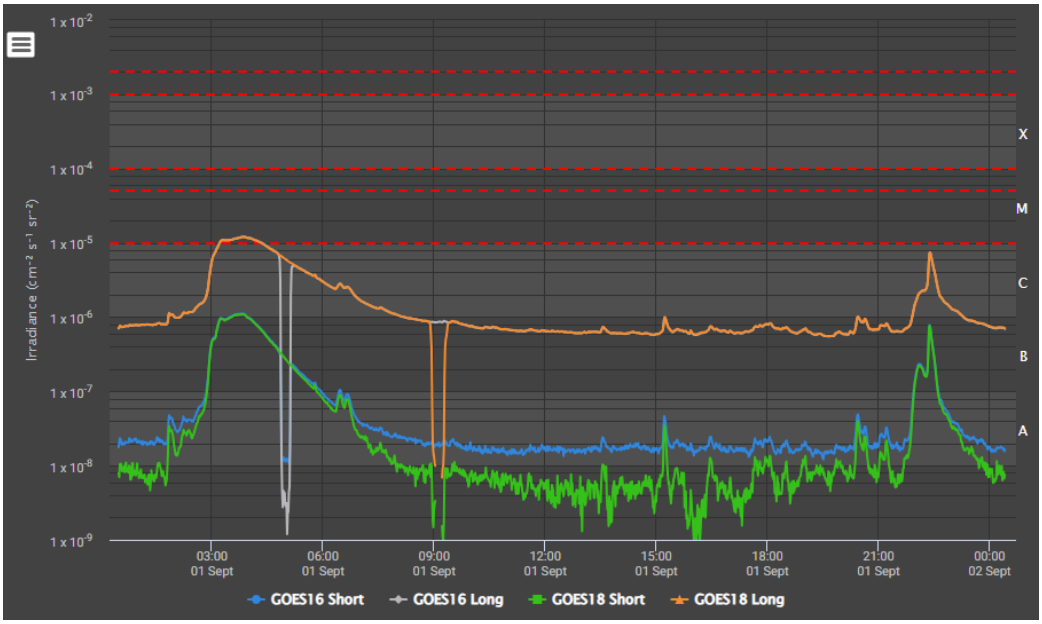
Radio Blackouts - X-Ray Flares:

Moderate to Low activity expected day 1 (02 Sep) with AR3413 showing ongoing potential for further M-flares. This is difficult to assess, as it is now approaching the northwest limb, but has maintained some complexity after the long period M1.2 flare on 01 Sep. This includes some notable looping visible in SDO-aia imagery (e.g. 211), that is showing the persistence of the arcade loops of the previous flare, and any reconnection of these has the chance to give another isolated M-flare. This region will rotate over the northwest horizon early day 2 (03 Sep), with the M-flare risk subsequently decreasing.

There are four other numbered active regions on the disc, however the majority of these are small and simple. The main exception is AR3417 which is a slightly more atypical group consisting of a number of small negative polarity spots with penumbra, but only very small positive spots without penumbra. Despite this, there is a reasonable magnetic canopy visible over the spot in SDO aia-imagery, and any further development will likely increase the M-flare potential.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	55	40	30	30
Very Active	R3 to R5 X Class	No	5	2	1	1

Figure 3:



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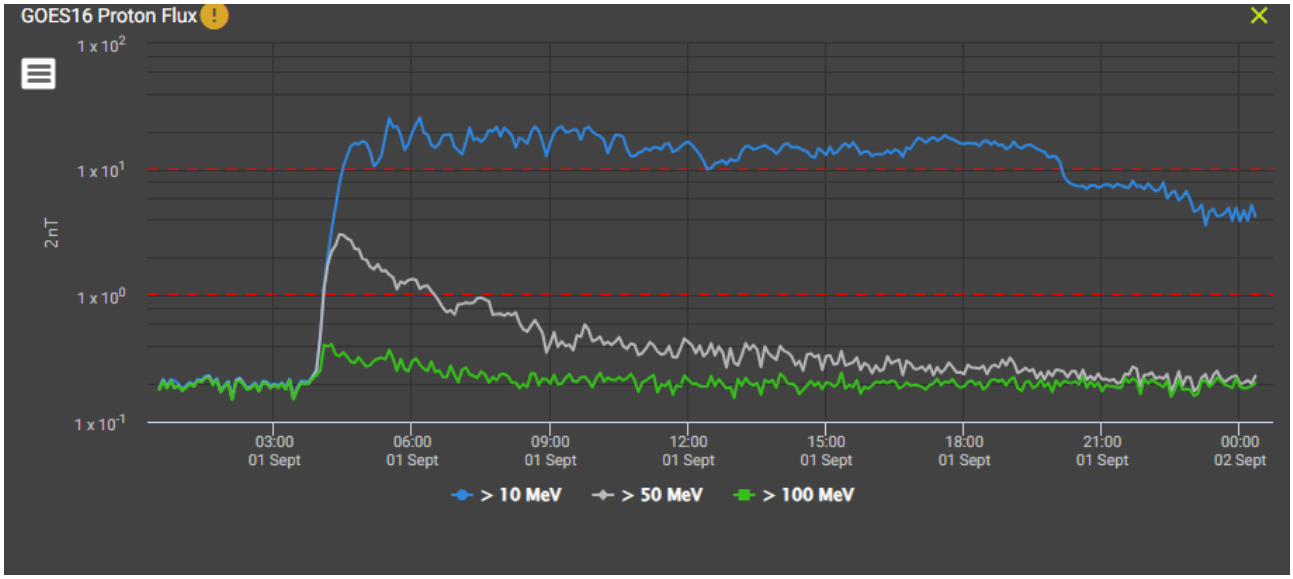
Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES-16 remains above background, but has now fallen below the S1 threshold after the recent enhancement due to the M1.2 flare of AR3415 on 01 Sep.

Flux is likely to continue erratically declining, although a brief increase is possible ahead of any CME arrival day 1 (02 Sep). Any further flares from AR3413 also have the potential to bring further enhancements to the flux, giving a slight chance of a further S1 event day 1, but decreasing through day 2 (03 Sep). As this region rotates further away on the far-side this risk subsides further, unless there is any further development of any of the sunspots currently on the disc, or any notable new sunspot emergence occurs.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	Yes	15	10	2	2
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: GOES16 Proton Flux



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High Energy Electrons Event (≥ 2MeV):

There is low confidence in this forecast, as it is very dependent upon the strength of the anticipated CME arrivals later day 1, and again on day 2 (02-03 Sep).

High energy (greater than 2 MeV) electron flux observed by GOES16 is currently at background levels, but is likely to see some increase due to the current high speed stream from coronal hole 40, perhaps rising to Moderate later day 1 (02 Sep) before any drop out caused by the CME arrivals. These are likely to increase electron populations throughout the Van Allen belts, but initially compressing them into lower orbits. As the solar wind pressure eases, mainly day 3 onward (04 Sep), flux is expected to increase to become Moderate to High, and likely becoming persistently High into day 4 (05 Sep). A further suppression in observed flux is possible later day 4 from a further fast wind enhancement from CH42, however by this stage the forecast is very low confidence.

The associated 24 hour fluence is expected be below the Active (1e8 integrated pfu) threshold day 1-2 (02-03 Sep), but with an increasing risk of rising above day 3 (04), and likely rising above day 4 (05 Sep). MOSWOC REFM is currently good guidance until the CME arrival, but will likely become poor for a time, once this occurs.

GEO Electron Environment	Level ($cm^{-2}\ sr^{-1}\ day^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	1	10	30	60
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

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